Fermilab

Acclerator Integrations Department/Accelerator Division

The Statistical Character of the Luminosity Readings from CDF and D0

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28 May 2004

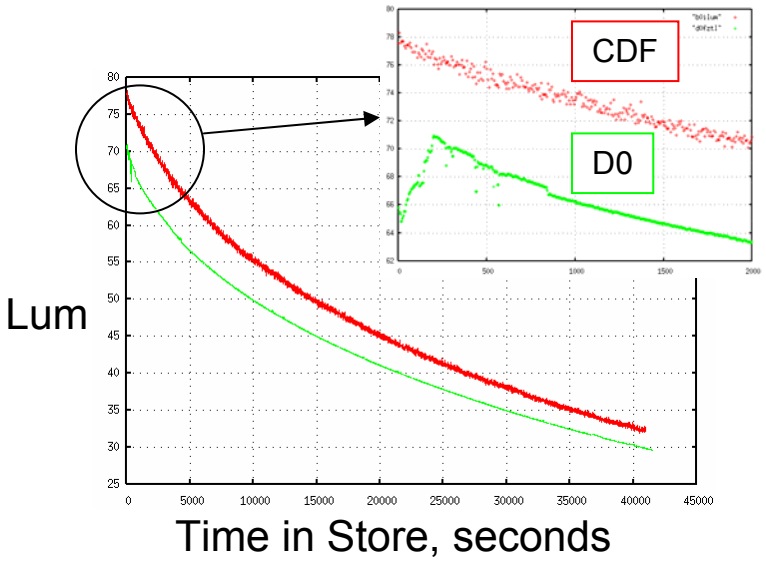
The instantaneous luminosity numbers from store 3534, which produced a record initial luminosity of 73.30E30, have been analyzed statistically. In particular, the RMS fluctuations in these numbers are determined.

The luminosity reading from D0 is substantially quieter than the signal from CDF. Moreover, the fluctuations in the CDF signal are comparable to the amount the luminosity decays over a reasonable averaging period. This fluctuation in the CDF luminosity reading leads to a systematic 1% overestimation of the initial luminosity.

I. Data Analysis

The ACNET devices that provide the experiments' luminosity readings are `C:B0ILUM` (for CDF) and `C:D0FZTL` (for D0). The data are obtained from the Lumberjack data logger, `Inst2`, which provides these data at 1 Hz.

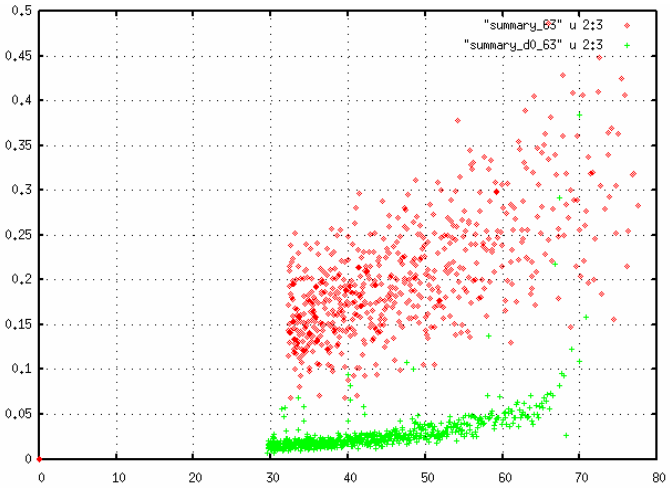
Figure 1 shows these luminosities for store 3534.



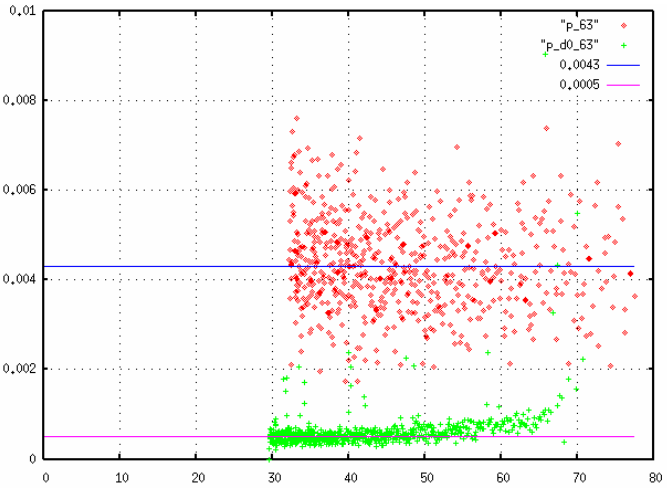
These data are then split into time bins of 63 seconds (chosen because the CDF luminosity is updated at approximately (1/7) Hz). The RMS deviation in the luminosity readings is calculated for each of these bins.

There are 620 63-second bins for the CDF data, and 633 bins for the D0 data. The average number of samples per bin is: (CDF) 10.0; (D0) 11.9.

This RMS, as a function of the instantaneous luminosity, is shown in Figure 2.



The fractional error (RMS/Luminosity) is shown in Figure 3:



The fractional fluctuations in the CDF luminosity reading approximately are constant with respect to the luminosity. D0's fluctuation has some luminosity dependence, but for the bulk of the time it is also constant. Moreover, there was something going on in the initial part of this store that fouled up D0's luminosity reading (see inset on Figure 1).

The approximate average RMS fluctuations are:

`C:B0ILUM` — 0.43%

`C:D0FZTL` — 0.05%

II. Implications and Observations

Several conclusions can be drawn from this measurement.

a. Error in Initial Luminosity Reading

The present algorithm for calculating the initial luminosities is to select the largest single luminosity reading during the initial phase of HEP, at the beginning of a store. Since the CDF

readback is fluctuating by about 0.43%, then we will, on average, choose a luminosity value slightly larger than the average luminosity at that moment. Therefore, one might expect to select an initial luminosity that is about 2×RMS larger than the statistical average. Since the peak luminosity from C:B0ILUM was determined to be 77E30, then the average at that moment would have been about

$$77 \times (1 - 2 \times 0.0043) = 76.3,$$

or about 0.86% too high.

b. Correcting the Error in Initial Luminosity Reading

For us to reduce this error in the readback of C:B0ILUM by a factor '*f*', then we'd have to use f^2 values for the average. If we want the readback on C:B0ILUM to be equal to D0's accuracy, 0.05%, then we'd have to average over:

$$(0.0043/0.0005)^2 = 73.96, 74 \text{ readings.}$$

It takes 480 seconds for the (1/6.5) Hz signal to yield 74 different readings. This will not work for the initial luminosity because the luminosity changes a lot over 8 minutes. Averaging over 58.5 seconds (9 readings) would reduce the error in the readback of C:B0ILUM by a factor of sqrt(9), to 0.16%.

c. Error in Averaging of Luminosity Reading

Assuming an exponential decay lifetime of τ = 6 hours (a typical, but rather lousy, value), over 8 minutes the luminosity is reduced by a factor of:

$$(1 - e^{-8 \text{ minutes}/6 \text{ hours}}) = 2.2\%.$$

Over 1 minute, the luminosity is reduced by a factor of 0.28%.

The decay over one minute is comparable to the random fluctuations observed in C:B0ILUM, 0.43% . The decay over 8 minutes is substantial.

For τ = 10 hours, the luminosity is reduced by a factor of 1.3% (for an 8 minute average) or 0.167% (for 1 minute average).

Another way of looking at it: How long does it take for the luminosity to be reduced by a factor 0.0043 at the beginning of a store?

$$0.0043 = (1 - \exp(-x/6 \text{ hours}))$$
$$x = 0.0259 \text{ hours} = 1 \text{ minute } 33 \text{ seconds.}$$

Therefore, the averaging period for the CDF luminosity reading must be a lot less then 1.5 minutes.

III. Conclusion

CDF should provide a more stable reading of their instantaneous luminosity. The fluctuations in the readings of C:B0ILUM are about 0.43%, which leads in general to an overestimation of CDF's initial luminosity by 1%.